ARMORED MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

Project No. 45
SPMEA 724-41

19 June 1945

1. PROJECT: No. 45 - Operational and Physiological Characteristics of the Tank T26E3, Second Partial Report. Subject: The Physiological Work Rates of the Driver and Loader in the Tank T26E3 in Relation to Fatigue and Efficiency of Performance.

a. Authority: Letter AGF File 470.8, dated 17 July 1944, GNRQT-6/91272.

b. Purpose: (1) To determine the physiological work rate of the driver in the Tank T26E3; (2) To determine the physiological work rate of the loader in the Tank T26E3; (3) To evaluate these work rates in relation to fatigue, efficiency of operation, and tolerance to severe humidity and heat.

2. DISCUSSION:

a. The physiological work rate, determined by oxygen consumption, is one measure of the muscular effort required to perform a task. If tasks within tanks can be accomplished at low work rates, the sparing of muscular effort will diminish crew fatigue and improve performance, particularly when the general conditions of work are poor. That changes in tank design can lower work rates without impairment of mechanical operation has been demonstrated in a previous report (1) in which the rates for specific duties were compared in tanks M4A3, M5, M24 and T23. Lower work rates were observed to result from improvement in driving controls, in ammunition stowage, and in the riding qualities of a tank.

b. In addition to fatigue reduction, low work rates allow men to work effectively in more severe conditions of heat and humidity.

c. Details of tests and results are given in the Appendix.

3. CONCLUSIONS:

a. The work rate of driving the tank T26E3 is moderate.

b. The work rate of loading in the tank T26E3 is high. Impaired loader performance will result from excessive fatigue and reduced tolerance to severe humidity and heat.

c. The efficiency of loading, measured by loading speed, is poor in comparison to previously studied tanks.

d. Higher work rates and reduced loading speeds result from increased size and weight of rounds, and are modified by the stowage of rounds.

4. RECOMMENDATIONS:

a. That measures be instituted in the T26E3, by restowage of rounds and/or by mechanical aids, to reduce loading work rates and to promote loading speed.

b. That the effect of stowage of rounds on the work rate, and the marked rise in work rate resulting from increased size and weight of rounds be carefully considered in future tank development.

NOTE:

Comments by Headquarters Armored Center with reference to this project are contained in the following indorsement:

P45 (25 May 45) GNREG 3d Ind.
HQ ARMD CENTER, Ft Knox, Ky. 13 June 1945

TO: Dir, AMRL, Ft Knox, Ky.

1. This headquarters concurs in conclusions and recommendations of the above report.

2. All evidence points to the great importance of keeping the weight of tank ammunition within the capabilities of the average man for effective handling and for the the maintenance of a high rate of fire. It is largely for this reason, too, that this office insists on the development of a high velocity gun with a minimum caliber and maximum armor penetration. The present trend towards a larger caliber is, in my opinion, definitely beyond the capabilities of the average man for handling the ammunition and the proposal for two piece ammunition for separate loading overlooks entirely the necessity for maintaining a high rate of fire in a tank.

/s/ C. L. Scott
C. L. SCOTT
Major General, U. S. Army
Commanding

1 Incl:
n/c

Submitted by:
Charles R. Park, 1st Lt, MC

APPROVED Willard Machle
WILLARD MACHLE
Colonel, Medical Corps
Commanding

2 Incls.
#1 - Appendix
#2 - References

APPENDIX

1. Selection of Tests:

a. The duties of individual crew members are similar in the tanks M4A3, M24, T23 and T26E3. The work rates for each duty have been found to vary considerably, however, from one tank to the next, and these variations have been attributed to the differences in structural design and operational characteristics of the tanks.(1)

b. Observation of the duties of the assistant driver, gunner, and tank commander within the tank T26E3, and observation of the structural and operational characteristics of the tank itself in respect to these crew positions indicated close similarity to the tank M24. The work rates of these crew members in the tank T26E3 were assumed therefore to be close to those previously reported for the tank M24(1) and less than the rates for either the driver or loader*. Direct determinations were not made. Structural and operational characteristics of the T26E3 should effect considerably the work rates of the driver and loader in comparison to other tanks and these duties were therefore selected for study.

c. It should be noted that the work of the driver is often for long periods of time, whereas the work of the loader is characteristically in short bursts of activity.

2. Procedure:

a. Three subjects were used for these tests (see Table 1). Each subject breathed through a plastic valve attached to a light helmet and expired air was collected in 200 L. Douglas bags. Duplicate analyses for O_2 and CO_2 were performed on each collection.

b. Results have been recorded in Cals/hr., Cals/m^2/hr., Cals/kg/hr., and Cals above resting.

Table 1

PHYSICAL CHARACTERISTICS OF SUBJECTS

Subject	Age	Ht. (ins.)	Wt. (kg.)	S.A. (m^2)
Bro	22	67	69	1.81
Bar	22	69	69	1.85
Rid	23	69	71	1.86

* Increase in work rates in the tank T26E3 for the gunner and tank commander over those found in the tank M24 will occur whenever these men assist in moving 90 mm rounds within the tank. Work rates for stowage of rounds in the tank T26E3 will probably be high (400-450 Cals/hr) and of long duration.

3. Description of Tests and Results:

a. Driving: Each subject drove a buttoned tank T26E3 over rolling, cross country terrain. The ground was dry, hard, and moderately rough. Numerous slopes of 5-10° were traversed. The equivalent of 1.3 right angle turns was made in each minute. The results are given in Table 2.

Table 2 - WORK RATES OF DRIVING

Subject	Cals/hr	Cals/m^2/hr	Cals/kg/hr	Cals Above Resting
Bro	207	114	3.0	117
Bak	194	105	2.8	104
Rid	191	103	2.7	101
AVERAGE	197	107	2.8	107

Collection period: 6-9 minutes.

b. Loading: The following aspects of the loader's task were selected for study: (1) Loading 5 rounds at maximum speed from the ready rack; (2) Loading 10 rounds at maximum speed from the ready rack; (3) Moving 10 rounds from the floor racks* to the ready rack; (4) Throwing 10 empty shell cases from the floor through the turret hatch. Each test was performed by 2 or 3 men. The results are listed in Table 3 below with the time required for each operation shown in the right hand column.

Table 3 - WORK RATES OF LOADING

Task Performed	Subject	Cals/hr	Cals/m^2/hr	Cals/kg/hr	Cals Above Resting	Time Seconds
Load 5 rounds from ready rack	Bro	904	499	13.1	814	63
	Rid	959	516	13.5	869	50
AVERAGE		932	508	13.3	842	57
Load 10 rounds from ready rack	Bak	1055	570	15.3	965	85
	Bro	985	544	14.3	895	91
AVERAGE		1020	557	14.8	930	88
Throw 10 empties from turret floor out thru hatch	Bro	1255	693	18.2	1165	25
	Bak	704	380	10.2	614	25
AVERAGE		980	537	14.2	890	25
Move 10 rounds from left floor racks to ready rack	Bak	640	346	9.3	550	135
	Bro	576	318	8.4	486	172
	Rid	634	341	8.9	544	129
AVERAGE		617	335	8.9	527	145

Recovery periods: 5-6 minutes.

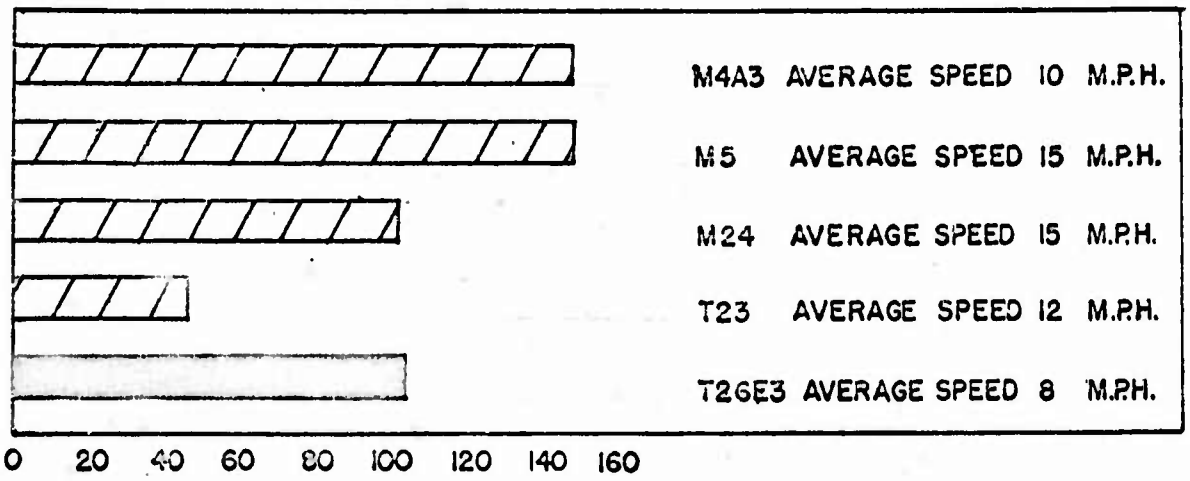
* Four rounds were taken from the bottom of the left floor rack next to the gun and 6 rounds from the top of the floor rack next to the ready rack. All rounds were properly secured.

4. Discussion:

a. Driving: In a previous study,(1) the work rate of the driver was found to be moderately high in the tanks M4A3 and M5, considerably reduced in tank M24, and markedly reduced in the tank T23. The reductions were attributed to the elimination of the effort of gear shifting, improvement in the positioning and functioning of the steering levers, and improvement in the riding qualities of the tank. Estimates from previous studies are combined with present tests in Chart No. 1 to show the relative position of the tank T26E3.

CHART-1

COMPARATIVE WORK RATES OF DRIVING *



CALS /HR ABOVE RESTING **

It is seen that the T26E3 compares well with previous tanks. It should be noted tha if work per distance covered is considered in place of work rate, the work in the oE3 is relatively greater because of the tank's slower driving speed.

Operation of the steering levers has been stated to require up to 100 lbs. of force.(2) This presumably accounts for the greatest part of the driver's work rate. The riding qualities of the tank in the driver's position were good and little effort was dissipated to maintain equilibrium. Comment was made that the levers were too far forward when driving buttoned down.

b. Loading: Studies of loading in the tanks M4A3, M24, T23, and T26E3 were made with two particular observations in mind: (1) the overall work rate; and (2) the efficiency of the operation as measured by loading speeds. The differences in work rates and efficiency appear to depend in turn on two factors: (1) The size and weight of the rounds, and (2) the stowage of the rounds and position of the loader relative to the breech. Chart No. 2 illustrates the comparative work rates and relative speeds of loading in 4 tanks.

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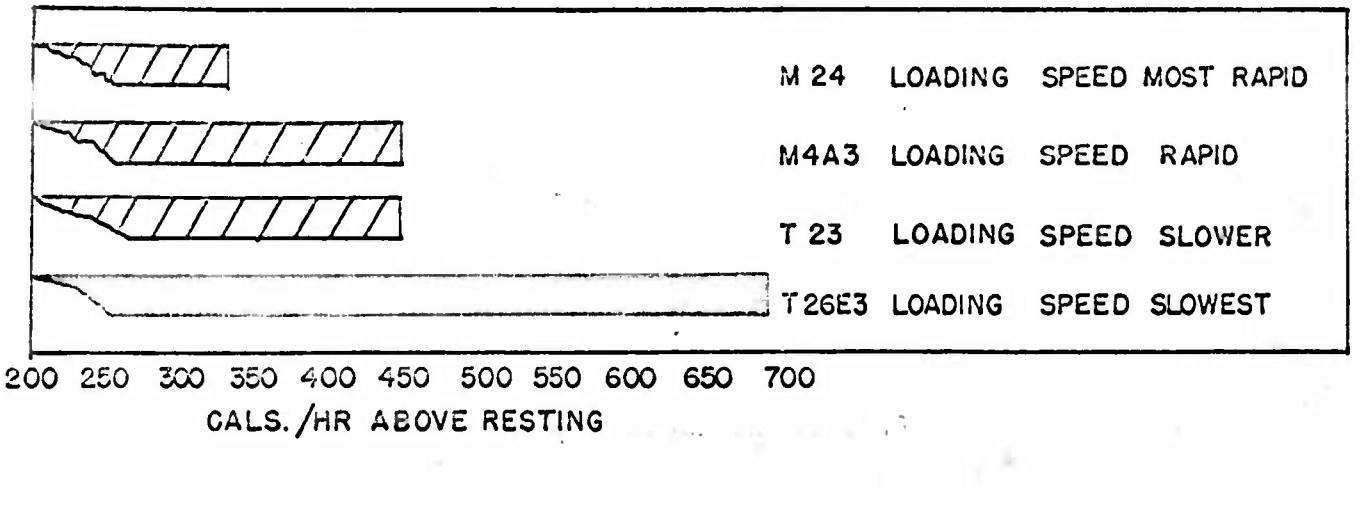
* Values reduced for "average man" of 150 lbs. weight and 5'8" height.

** This figure gives rate of task per se. Add 90 Cals/hr for total work rate in Cals/hr.

CHART-2

COMPARATIVE WORK RATES OF LOADING *



The difference in work rate between the tank M4A3 and tank M24 was attributed to better ammunition stowage in the latter allowing more efficient operation. The high work rate with a slower loading speed in the tank T23 was attributed chiefly to larger, heavier 76 mm rounds. In the tank T26E3 a very marked rise in work rate and further reduction in loading speed is seen. These effects are chiefly the result of the size and weight of the 90 mm rounds, but in addition, rounds are not readily accessible except in the case of the ready rack and top layer of the floor racks to the left of the breech.

The work rate of loading in the T26E3 arises from several separate operations. The first is the loading of rounds into the breech from the ready rack. This may be accomplished rapidly but demands a very high work rate. The second is moving rounds from less accessible racks to the ready rack in preparation for further firing. This is an operation performed at a lower work rate but for a longer period of time. The third is disposal of empty brass which is quickly accomplished but still entails a high work rate (see Table No. 3). Chart No. 2 is based on loading 10 rounds, disposing of empty brass, and replacing in the ready rack 10 rounds from the most accessible racks in each tank studied. The rates are higher than would be the case were the subjects more experienced and unencumbered by the respiratory apparatus, but probably not higher than in combat where nervous tension will appreciably raise the work rate.

The work rate in the T26 computed for loading, throwing out brass, and replacing 10 rounds averages 785 cals/hr for a period of 4 minutes, 18 seconds. To indicate the significance of this in more familiar terms, the work rate is the same as that determined for an athlete running one half mile in the same period of time. Considerable muscular fatigue would be inevitable unless the subject were exceptionally physically fit.

Should the loader be called on to load 20 to 30 rounds in rapid succession, it seems highly probable that the physical effort would be exhausting or

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* Values reduced for "average man" of 150 lbs. weight and 5'8" height.

that a necessary work rate reduction would be made by slowing the loading speed. Work rates of this magnitude will impair the ability of the loader to operate in severe conditions of humidity and heat. Physical fatigue with resultant impaired performance may be anticipated should the loader be required to load the entire stowage of the tank one or more times during the course of a day's operations. Such a task involves lifting and moving 2940* lbs under mechanically disadvantageous conditions.

A recent report of recommendations relative to present and future development of armored equipment sets 5 Cals/kg/hr as the top acceptable limit for work rates up to 1 hour's duration within armored vehicles.(3) This limit will be frequently exceeded by the loader in the tank T26E3.

The loading speeds as measured in these tests (Table 3) are considerably below possible loading speeds obtained by more experienced subjects and by men unencumbered by respiratory apparatus. The trend toward lower speeds with larger rounds is, however, valid. It seems likely that loading from the ready rack can be accomplished sufficiently rapidly, but that loading from other racks may at times be too slow.

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* Each round weighs approximately 42 lbs.; 70 rounds are stowed.

REFERENCES

(1) Armored Medical Research Laboratory, Sub-Project No. 5-13, dated 24 March 1945. Appraisal of Kind and Degree of Physical Effort Required of Tank Crews in Relation to Fatigue.

(2) Office of the Chief of Ordnance, Detroit, dated 22 March 1945. Subject: Minutes of Meeting on Deficiences on Heavy Tank, T26 Series.

(3) Report of the Armored Equipment Board, Headquarters Armored Center, Fort Knox, Ky., dated 17 November 1944. (SECRET)